GENERATION OF

Feasible Alignments

Engineering

HAMILTON-WENTWORTH RAPID TRANSIT PROJECT

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To:	The Regional Municipality of Hamilton-Wentworth

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RESEARCH UNIT FOR
McMASTER
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CONTENTS

1.0 GENERAL

1.1 Introduction
1.2 The Process
1.3 Summary

2.0 SOIL MECHANICS

2.1 Introduction
2.2 Background
2.3 Lower Zone
2.4 Upper Zone
2.5 Escarpment Zone
2.6 Comparison of Escarpment Routes
2.7 Conclusions

3.0 MUNICIPAL

3.1 General
3.2 Task B1
3.3 Data Requested and Obtained
3.4 Review of Data
3.5 Major Utility and Municipal Service Facilities

4.0 STRUCTURAL

4.1 General
4.2 Alternative Alignments
4.3 Relative Costs
4.4 Review of Design Criteria

5.0 ALIGNMENT DRAWINGS

6.0 APPENDIX A
Geotechnical Summary Documents

7.0 APPENDIX B (2 volumes)
Trunk Services Drawings

1.0 GENERAL

1.1 INTRODUCTION

This document summarizes the activities of the Engineering Team in the task of generating alignments for the rapid transit facility. In the process, alignments were eliminated which were not feasible, viable, or practical. The task required collaboration with the Planning Team, as well as co-ordination with, and input from and to, U.T.D.C. staff and other consultant teams.

It is to be noted that, while this document accurately reflects the opinions and conclusions reached to date, some of the material anticipated has not yet been available. It is therefore possible that some modifications may be required as further information is introduced.

1.2 THE PROCESS

1.2.1 There were two main components to the team's efforts during the task. The first was primarily a responsive role to the main route generation effort by the Planning Team, and the second was that of identifying, assembling, and reviewing the wealth of data existing on the study area in preparation for further intensive spot investigations of specific alignment segments. This data bank will provide the basis for the increasingly intense investigation of a decreasing number of routes as the study progresses.

1.2.2 Suggested routes were considered, some were eliminated, and some variations were suggested. The prime thrust of the Engineering Team's input was of course on the "constructability" of suggested alignments, and the resulting alignments shown on the accompanying 15 drawings have been judged to be feasible. There will be, however, conditions attached to the "feasibility" of many segments of several alignments which will be mentioned herein, and assessed in more detail in the next study phase.

1.2.3 Probable the most significant data assembly and evaluation component was produced by the soil mechanics group. The amount of data is so extensive

that it is included as an Appendix to this document. Section 2.0 summarizes the work sufficiently for general reporting purposes, but Appendix 'A' will serve as a valuable reference for subsequent more detailed use.

1.2.4 There has been a similarly extensive, although not exhaustive, assembly of municipal services and utilities data. Much of this has been compiled on the combined overall plans of services also included as an Appendix to this document. This general overview has simplified the identification of possible conflicts of the many routes investigated, and will be the basic reference for the more intensive detailed investigations to follow. Major service routes are shown on the enclosed drawing No. X-80629-G10

1.2.5 While providing significant contribution to the development of feasible alignments, the structural elements of the team developed relative cost factors for use in assessing route viability and the subsequent comparison of alternatives. Preliminary consideration was also given to design standards and criteria, construction methods and constraints, and specific foundation requirements.

1.3 SUMMARY

1.3.1 A substantial data bank has been summarized on subsurface conditions, and on municipal services and utilities, which should serve as a valuable reference for the remainder of the study.

1.3.2 It is concluded that the rapid transit system can be built on any of the proposed alignments and will be primarily an elevated guideway, with some tunnel sections possible in the escarpment crossing. The more notable engineering features may be generally described in three zones as follows.

1.3.3 Construction on the Mountain, or Upper Zone, is expected to be fairly routine, with relatively good foundation conditions existing, and normally expected conflicts with other services.

1.3.4 Foundation conditions downtown in the Lower Zone are not as good as in the Upper Zone, but are not expected to present an unusual challenge. The

physical constraints imposed by the proximity of major buildings, the profusion of other services, and high traffic flows, will, however, have major impacts on route selection, construction methods, and in fact on every aspect of the implementation program.

1.3.5 The crossing of the Escarpment Zone was without doubt the most difficult aspect of the engineering component of the route generation process. The soils conditions and the escarpment profile vary significantly. Any of the suggested alignments will require fairly elaborate and extensive foundation treatment, particularly in view of the low tolerance of the I.C.T.S. for foundation movement.

2.0 SOIL MECHANICS

2.1 INTRODUCTION

This section summarizes the appended Geotechnical Summary Document for the Major Task B1 portion of the present study. In order to assist in the identification of twelve alternative horizontal alignments, an extensive geotechnical data review was conducted. It should be pointed out that due to the widely spaced distribution of data in some areas, and great variety in data sources, generalizations were necessary in some instances. As a result, although the assumptions made should reasonably reflect the actual conditions to which they refer, the design details with regard to bearing capacities, slope movement, ground water levels and the like must be proven in a subsequent drilling and testing program.

2.2 BACKGROUND

The most prominent physiographic feature of the study area is the Niagara Escarpment, and as such, presents the greatest challenge from a geotechnical point-of-view. For the purpose of generalization, the study area has been divided into three (3) zones, i.e., the Upper Zone (above the escarpment to the south), a Lower Zone (from the foot of the escarpment to the northern extent of the study area), and the Escarpment Zone. This summary addresses the soil, rock and ground water conditions as well as the associated engineering concerns and design possibilities in each of these zones.

2.3 LOWER ZONE

2.3.1 Soil and Bedrock

Under varying depths of fill, the soils in the Lower Zone generally consist of lacustrine silty sand, sand as well as sand and gravel which overlie silty clay to clayey silt deposits of the Halton Till.
Bedrock in the Lower Zone consists of thinly bedded red shale of the Queenston Formation. The depths to bedrock vary from 10 to 20 feet, in the vicinity of the Escarpment, to as much as 140 feet in the vicinity

of a buried pre-glacial valley which was generally oriented with an East-West axis across the study area in the vicinity of King Street.

2.3.2 Ground Water

Two ground water tables have been observed in the Lower Zone. An upper perched condition exists in some localities in fills and lacustrine deposits of gravelly sands, at depths of 5 to 15 feet. A second lower ground water table is found in the Halton Till at a depth of about 35 feet. Generally, no serious ground water problems are anticipated and minor seepage should be easily controlled by the use of properly constructed sumps and conventional pumping techniques. However, the possibility exists that excavation in areas of localized perched ground water conditions may require more positive dewatering measures, i.e., well-points, etc.

2.3.3 Problem Areas & Design Possibilities

Generally, the problems expected in the Lower Zone do not appear to be of major concern from a geotechnical point-of-view and are as follows:

1. Marginal bearing capacities are available for spread footings in the undisturbed native soils;

2. Excavations to significant depths below localized perched ground water conditions may require positive dewatering measures; and

3. Large dimension foundations may come into conflict with existing structures, foundations, services, etc.

Crossing routes in the Lower Zone, such as at the TH & B Railway may require span lengths significantly longer than the norm and result in column loads beyond the capacity of native soils in the area. Generally, however, column loads are not expected to be excessive and spread footings are certainly feasible provided that the normally tolerated settlements of 1 inch total and 3/4 inch differential are acceptable for the system under consideration. If these settlements are unacceptable, then piled foundations to bedrock will be required. The advantage of piled foundations to bedrock is that there is considerabley less conflict with existing structures, services, etc. and less concern about ground water conditions if driven piles are used. Should piled foundations be required,

however, it should be pointed out that the pre-glacial buried valley feature which is generally oriented along King Street, significantly affects the bedrock depth in the study area. The greater length of piles required for East-West routes in this area will certainly increase the foundation costs for this portion of the system.

2.3.4 Spread Foundations in Soil

Spread footings founded in the undisturbed lacustrine silty to gravelly sand or Halton Till may generally be designed for allowable bearing pressures of 2 to 5 tsf. Footings designed for these allowable bearing pressures should experience settlements well within the normally tolerated limits of 1 inch total and 3/4 inch differential.

2.3.5 Piled Foundations to Bedrock

Driven piles should consist of concrete filled closed-end pipe piles, precast concrete piles or steel H-section piles. Steel H-section piles are expected to meet refusal at greater depths and may be subject to relaxation. The advantage of H-piles is that they produce less vibration during installation and the frictional components of this pile type may be required to compensate for uplift forces from the structure.
Closed-end pipe, precast concrete piles, or steel H-piles driven to practical refusal may be designed for allowable bearing capacities of 70 to 100 tsf. Retapping of all piles in a pile group after completion of driving will most likely be necessary. Reinforced concrete caisson piles founded on the Queenston shale bedrock may also be acceptable if the prevailing ground water conditions permit. Caissons may be designed for allowable bearing capacities of up to 25 tsf.
Higher bearing capacities may be available for piled foundations but must be confirmed by load tests and detailed inspection in conjunction with use of the Pile Driving Analyser during installation.

2.4 UPPER ZONE

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2.4.1 Soil, Rock and Ground Water Conditions

The soil conditions in the Upper Zone consist primarily of lacustrine deposits of silty clay to clayey silt. The exception being in the south-west corner of the study area (west of Upper Wellington Street and south

of Fennell Avenue) where deposits of silty clay to clayey silt till are encountered.

Bedrock is encountered at depths of 5 to 40 feet and consists of dolomite of the Lockport Formation (Elevation 610 to 720 feet).

The ground water table in the Upper Zone is generally found at or near the overburden-bedrock interface. In the area of Fennell Avenue to Mohawk Road, however, the water table is observed at a depth of 10 to 15 feet. Generally,excavations for foundations should experience no serious ground water problems.

2.4.2 Foundations

Foundations in the Upper Zone should experience no serious difficulties. Conflicts with existing structures, services, etc. should be considerably less than anticipated in the Lower Zone.

Spread footings, founded on the undisturbed native soils of the Upper Zone, may be designed for allowable bearing pressures of 2 to 4 tsf. Footings designed for those bearing pressures should experience settlements less than the normally tolerated limits of 1 inch total and 3/4 inch differential. If these settlements cannot be accommodated, then foundations on bedrock will be required.

Due to the shallow bedrock depths encountered in some areas of the Upper Zone, shallow footings founded on bedrock and designed for allowable bearing pressures of 10 tsf are certainly feasible. In the event that the depth of overburden makes spread footings on bedrock an impracticality, piled foundations to bedrock may be required. Piled foundations may consist of socketted caissons of steel "H" and closed-end pipe piles driven to practical refusal. Piled foundations may be designed for allowable bearing capacities of 70 to 100 tsf. Provisions for uplift may have to be considered.

2.5 ESCARPMENT ZONE

2.5.1 Soil, Rock and Ground Water Conditions

The escarpment consists of an alternating sequence of relatively flat-lying hard dolostones and soft shales. Erosion of these rock types gives rise to the accumulation of a talus or debris slope at the foot of the

escarpment. The talus varies in depth from about 20 to 60 feet with areas probably as deep as 90 feet to the East of the CHARM project. The talus slope is considered to be marginally unstable and tends to move slowly downhill particularly where influenced by ground water or surcharged by additional debris material. Ground water problems in the vicinity of the escarpment appear to be limited to artesian pressures in the Queenston shales at the foot of the slope.

2.5.2 Problem Areas and Design Possibilities

Various routes have been proposed up and through the escarpment. These routes will traverse the different foundation materials to different degrees. Each of the foundation type alternatives are, therefore, discussed.

2.5.3 Caissons through Talus to Bedrock

Where routes traverse the talus slope, caissons supporting the rail system will have to be taken down through the talus to be socketted into bedrock. Due to the mobile nature of the talus and given the assumed low movement tolerances of a system of this nature, the system cannot be founded on the talus. Caissons will have to be designed to take into account lateral loading by the talus material. Consideration may have to be given to the improved stabilization of certain areas of talus on some routes, e.g., by means of drainage techniques. In general, at the base of socketted caisson holes, design net bearing pressures of 30 and 70 tsf could be developed on shale and dolostone respectively.

Escarpment crossing routes on the north (down face) side of the existing accesses (e.g. Claremont Hill Mountain Access Road and James Mountain Road) were immediately ruled out due to expected talus movements as well as the extremely steep bedrock face (up to 50 to 60 degrees from the horizontal) in some areas.

2.5.4 Columns on Rock at Shallow Depth

On certain routes, e.g., along the Claremont Access and Jolley Cut (CHARM Project) where extensive excavation of talus material has been undertaken, it would be possible to found the system on conventional spread footings on rock at the surface or at shallow depth. In general, design net bearing pressures of 5 to 10 tsf could be developed on the

shale and dolostone respectively. Proposed routes along the southern (inside) sides of existing highways may necessitate cutting back existing rock faces in order to accommodate the proposed structures. The design of stable cut slopes will be necessary taking into consideration the rapid deterioration of shales in the escarpment ard the ongoing maintenance problem experienced, for example, along the Jolley Cut.

2.5.5 Tunnel through Talus

Tunnelling through talus appears to be the most difficult problem from a geotechnical point of view. Borehole information suggests the talus consists of large dolostone blocks in a matrix of clayey silt. Excavation through, and support of, this material will be problematic. The marginal stability and on-going creep in the talus will mean that differential movements between the talus and the bedrock will have to be taken into consideration in the design of this part of a tunnel. Open cut sections through the talus are not recommended as this is likely to promote instability in this material. Extensive stabilization will be necessary, e.g., retaining walls, drainage etc. and even this will not necessarily guarantee a stable situation. Flexible track systems which can be adjusted to compensate for movements may be required. From a geotechnical point of view, tunnelling through talus would best be avoided or at least kept to a minimum.

2.5.6 Tunnel through Rock

A tunnel through rock will pass through an alternating sequence of near-horizontal hard dolostones, limestones and sandstones, as well as softer more erodible shales. Rock tunnelling should not present any serious geotechnical problems. The design of a tunnel should, however, take into account movements that will likely occur as a result of the release of high built-in horizontal stresses in the rock mass. These movements can probably be best accommodated by a combination of construction scheduling, monitoring and the installation of a deformable tunnel liner system. Because the strata are near horizontal, it is considered preferable from a geotechnical point of view to construct the tunnel normal to the face. Horizontal movements in rock walls along a tunnel of this alignment would be relatively uniform and could be accommodated. An oblique alignment could give rise to differential movements in tunnel walls due to the

presence of vertical joint sets in the rock mass. These movements would be more difficult to accommodate.

Despite the variability in strength and hardness of the various rock formations in the escarpment, tunnel excavation can probably be best accomplished by means of a tunnel boring machine. Temporary support measures are likely to be necessary particularly in the shale formations which will probably have a relatively short stand-up time. Deterioration of these rocks can probably be prevented by the use of bolting, prior to the installation of a liner system which could be of the segmental concrete type with suitable provisions (deformable backing, for instance) for horizontal deformations.

It is indicated in the literature that a number of the upper dolomite formations are potential aquifers (water bearing), although it is not indicated whether this is the situation in close proximity to the escarpment. Boreholes and suitable pumping tests will be necessary to assess the magnitude of this problem as it will determine the required direction of excavation.

Explosive gas has been encountered at least at one location on the Hamilton Mountain immediately to the east of the project area. This condition can be accommodated during construction and would not rule out a tunnel alternative.

Portal construction must be taken into consideration particularly on the downtown side of the escarpment. Stabilization of the rock mass in the vicinity of the portal will be necessary to prevent rock falls and on-going deterioration of shale strata. The proximity of existing structures must be taken into account and the effect of portal construction on the long term stability of these structures should be considered.

2.6 COMPARISON OF VARIOUS TYPICAL ESCARPMENT CROSSING ROUTES

This section is presented only as a guideline to indicate the relative cost of the various foundation types required for several escarpment crossing routes. A description of the required foundation types with comments regarding concerns and design possibilities as well as assigned geotechnical costing factors for each foundation type is presented in Table 1A. Eight potential routes traversing the escarpment have been previously proposed and

a geotechnical cost rating has been assigned for the various routes (see Table 1B).

It should be emphasized that the geotechnical costing factors presented are approximate only and do not take into account the cost of the elevated guideway structure. The geotechnical cost ratings presented in Table 1B reflect only the relative cost of "Foundations" for the various foundation types. This results in an extremely high relative costing factor for tunnels since, according to this criteria, the tunnel is considered as a foundation rather than as a structure. However, when the cost of the elevated guideway structure, which is necessary for the other foundation types and not required in a tunnel, is taken into account, the costing factor is significantly reduced. A more appropriate cost comparison of the various escarpment crossing routes may be derived by using the relative costing factors presented in Section 4.3 which includes the cost of the guideway structure.

The construction of the CHARM Project resulted in the removal of large volumes of talus particularly in the vicinity of the Claremont Hill Access Drive and the Jolley Cut. This has resulted in the subsequent stabilization of the exposed rock formations. The proximity of bedrock to the ground surface along these two routes and the fact that cut slopes have been stabilized makes these two proposed routes (3 and 4) more attractive than for example proposed routes 1 (James Street Mountin Road) and 5 (oblique route to Upper Wentworth Street). It appears that these latter routes will require deep (20 to 70 feet) caissons through talus to bedrock as well as stabilization of the escarpment face and slope adjacent to these routes.

2.7 CONCLUSIONS

The following conclusions will certainly affect the difficulty of design, construction and hence the costs of the various items discussed. However, none of these factors should be considered as prohibitive for the foundation or route type discussed.

1. No serious geotechnical problems are expected in the Lower and Upper Zones. Piled foundations may be necessary depending on the settlement tolerances of the system;

2. Definite stability problems have been identified on the talus slopes of the Escarpment. As such, the length of traverse on the talus as well as the depth of talus under contention should be kept to a minimum. Existing escarpment crossing routes such as the Claremont Hill Mountain Access Road and the Jolley Cut appear preferable since extensive excavation of talus material and rock stabilization has already been carried out. Crossing routes on the north (down face) side of the existing accesses have been ruled out due to the expected talus movements as well as the extremely steep bedrock face (up to 50 to 60 degrees from the horizontal) in some areas;

3. Tunnel through talus will be problematic and should be avoided or kept to a minimum due to the expected movements and instability of the talus; and,

4. Tunnels normal to the escarpment face are preferable to oblique tunnels.

PRELIMINARY GEOTECHNICAL COSTING FACTORS

FOUNDATION TYPES	CONCERN	DESIGN	GEO. COST FACT.
TYPE A Foundation on soil (above & below escarpment)	MINOR • bearing capacity marginal • localized perched water	(dependent on load and movement requirements) • spread footings near escarpment • localized H-piles	1
TYPE B Foundation through talus to rock	MAJOR • lateral creep of talus • lubrication by water • settlement potential • differential settlement between talus & rock • lateral loads on caissons	(dependent on load and movement requirements & monitoring results) • caissons to rock • systems to minimize lateral loads on caissons • drainage/stabilization of talus	~2
TYPE C Foundation on rock at shallow depth	MINOR • deterioration of cut slopes • rock falls	• spread footings to rock • cut slope angles • stabilization & safety requirements	~21
TYPE D Tunnel through talus	PROBLEMATIC • excavation through limestone blocks • creep and support • marginal stability of talus • groundwater • differential movement between talus & rock	(dependent on load & movement requirements & monitoring results) • temporary & permanent support • drainage of talus • system to adjust rail	~25
TYPE E Tunnel through rock	MODERATE • mixed hard dolostone and soft shale • excavation method • accomodation of natural horizontal stresses • aquifers and groundwater • portal stability • methane gas • durability and stand-up time of shales	• tunnel normal to face • tunnel boring machine • bolting, etc. • yeilding liner	~20

TABLE 1A

PRELIMINARY GEOTECHNICAL COST RATING OF TYPICAL ESCARPMENT ROUTES

ROUTE 1				ROUTE 2				ROUTE 3				ROUTE 4			
Dist.	*	GCF	GCR	Dist.	*	GCF	GCR	Dist.	*	GCF	GCR	Dist.	*	GCF	GCR
2500	(A)	1	2.5	1500	(A)	1	1.5	2600	(A)	1	2.6	2600	(A)	1	2.6
1800	(B)	2	3.6	500	(B)	2	1.0	2200	(B)	2	4.4	1300	(B)	2	2.6
200	(C)	1	0.2	200	(D)	25	5.0	1300	(C)	1	1.3	3400	(C)	1	3.4
				1200	(E)	20	24.0								
4500			6.3	3400			31.5	6100			8.3	7300			8.6

ROUTE 5				ROUTE 6				ROUTE 7				ROUTE 8			
Dist.	*	GCF	GCR	Dist.	*	GCF	GCR	Dist.	*	GCF	GCR	Dist.	*	GCF	GCR
3000	(A)	1	3.0	1100	(A)	1	1.1	2400	(A)	1	2.4	600	(A)	1	0.6
2000	(B)	2	4.0	300	(B)	2	0.6	1300	(B)	2	2.6	1300	(B)	2	2.6
								1000	(C)	1	1.0	200	(C)	1	0.2
1000	(E)	20	20.0	200	(D)	25	5.0	400	(D)	25	10.0	1600	(E)	20	32.0
				2200	(E)	20	44.0	200	(E)	20	4.0				
6000			27.0	3800			50.7	5300			20.0	3700			35.4

NOTES:

* - FOUNDATION TYPE - see Table 1A

GCF - Geotechnical Costing Factor

GCR - Geotechnical Cost Rating, derived by totalling the multiples of GCF and the appropriate distance expressed in thousands of feet.

All distances are approximate.

ASSUMPTIONS:

(i) End points of routes: Y, about 500' north of toe of slope about 2000' south of escarpment crest
(ii) Tunnel distances on 10% grade
(iii) On oblique routes up escarpment, caissons not on north side (downslope) of roads

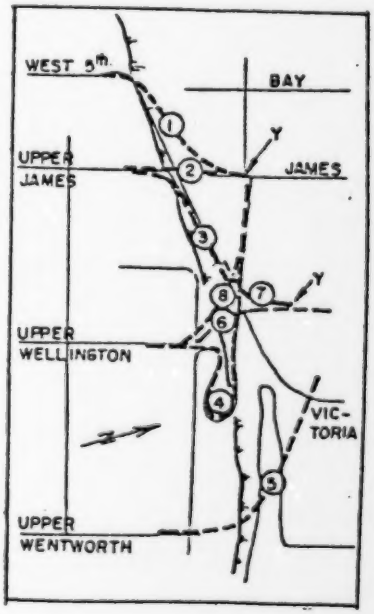


TABLE 1B

3.0 MUNICIPAL

3.1 GENERAL

The construction of the I.C.T.S. or any similar transit facility in an existing developed area will create temporary and permanent conflicts with existing roads and buried and overhead utilities and municipal services. Since the I.C.T.S. will generally be elevated, conflicts with buried utilities and services will usually only occur at the support columns. Aerial utilities may be more generally affected. If tunnelling of the transit facility is proposed, then conflicts with buried utilities and municipal services can be expected along all lengths of shallow tunnel within existing road allowances and also in some areas of deep tunnel.

The City of Hamilton, within the study area, is fully serviced. Therefore, nearly all streets have sewers, watermains, gasmains, Bell and hydro cables. In addition, several of the streets also have overhead trolley bus feeders and traffic control devices at major intersections. It is unlikely that the rapid transit facility can be constructed on any street without interfering with at least one of the utilities or municipal sercices. In most cases, several will be affected. There may be some flexibility in the location of support columns which would permit consideration of a location which would reduce the impact on municipal services and utilities.

If the transit facility is constructed with support columns located within existing road pavements, it may be necessary to widen the roads to provide adequate traffic flow. This will involve not only reconstruction but may result in additional utility and service relocations. For example, a road widening could necessitate the relocation of Bell and hydro poles even though these are not directly affected by the transit guideway.

Some utilities can be relocated relatively easily. These include small diameter gasmains, watermains, minor overhead and buried Bell and low voltage hydro cables. Sewers, even the smaller sizes, can be more difficult to relocate since gravity flow must be maintained. Siphons can be utilized to pass under obstructions but are undesirable and should be avoided.

Relocation of utilities and municipal services may be temporary and only required during construction of the transit facility. Other utilities and municipal services will require permanent relocation within the road allowance or complete re-routing along other streets or service corridors.

3.2 TASK B1

The Municipal portion of the initial route selection process (Task B1) has been divided into four main components:-

- To obtain and review plans of all the utilities and municipal services in the study area.
- To identify the trunk utility and service locations which pose constraints to route selection due to the difficulty and high cost of relocation.
- To identify potential conflicts with services and utilities of proposed routes to assist in the generation of the twelve alternative alignments for more detailed study in Task B2.
- To suggest alternate routes which would avoid major conflicts where possible.

3.3 DATA REQUESTED AND OBTAINED

The following agencies and companies have been requested to provide utility and service locations in the study area:-

Regional and Municipality of Hamilton-Wentworth - Sewers, Watermains, and Traffic Signal Devices

City of Hamilton - Truck Tunnels, Central Utilities Plant, etc. associated with the Jackson Square Redevelopment Area

Union Gas

Bell Canada

Hamilton Hydro

Ontario Hydro

C.N.C.P. Telecommunications

T.H. & B. and C.N. Railways

Cable T.V. Companies (four separate companies)

St. Joseph's Hospital
Hamilton Street Railway - Trolley Bus Routes and
Overhead Feeds

Full sets of plans covering the study area have been received for sewers, watermains, gasmains, aerial hydro, C.N.C.P. Telecommunications, trolley bus lines and feeders and traffic signal cables.

Bell Canada declined to produce complete sets of plans on the grounds of confidentiality. However, Bell agreed to provide limited information on trunk duct locations to assist in route selection. When the route alternatives have been narrowed down, Bell will mark up drawings to show all their facilities along the selected routes.

3.4 REVIEW OF DATA

The plans received were reviewed and from them drawings have been produced showing the location of the more important municipal services and utilities as follows:

Drawing No.		
X-80629-G1	Sewers	- 18" Ø and over
X80629-G2	Watermains	- 18" Ø and over
X80629-G3	Gasmains	- 4" Ø and over
X-80629-G4	Hydro	- 4000 V and 13.8 KV buried and aerial cable routes
X-80629-G5	Bell	- Major buried and aerial cables
X-80629-G5	C.N.C.P.	- All buried and aerial cable routes
X-80629-G6	Cable T.V. & Traffic Signal Control Cable	
X-80629-G7	H.S.R.	- Trolley bus routes and feeders
X-80629-G7	C.N. & T.H. & B.	- Railway Rights-of-Way

These drawings are included in Appendix B.

3.4.1 Sewers

The older areas of the City of Hamilton have traditionally been serviced by a combined sanitary and storm sewer system. In recent years, separate storm and sanitary sewers have been installed in newly developed areas. In some locations, separation of the existing combined sewer systems has been undertaken as reconstruction has become necessary due to

road works, redevelopment or the need to provide additional capacity. Within the City, all sewers are under the jurisdiction of the Regional Municipality of Hamilton-Wentworth.

In the study area south of Mohawk Road, all sewers are separate. North of Mohawk Road, the majority are combined sewers but there are notable exceptions such as the storm sewers constructed in connection with the Claremont Hill Mountain Access Road (CHARM).

Sewers south of Fennell Avenue,including the separate sewers south of Mohawk Road,all flow north into a large combined box sewer on Fennell Avenue. This sewer flows west to east right across the study area. Most of the study area between the escarpment and Fennell Avenue drains to another large combined box sewer which flows north on Wellington Street, west on Inverness Avenue and north on Upper James Street. This sewer continues down the escarpment via a drop shaft from Upper James Street to James Street South.

Below the escarpment there are major combined sewers flowing north on James Street, John Street north of Main Street, Catharine Street, West Avenue north of Main Street and on Victoria Avenue. Major east-west sewers are located on Robinson Street and Main Street west of James Street and Main Street from Spring Street to Victoria Avenue.

Sewers are generally located under or close to the centre of the roads with approximately nine feet of cover. Trunk sewers may be considerably deeper.

3.4.2 Waterworks

Water Pumping Station H2 is located at the south end of Ferguson Avenue. Several large diameter watermains are associated with this pumping station. If construction of the transit facility were proposed in this vicinity, there would be a number of potential conflicts.

Associated with the station are 30" and 36" Ø mains on Charlton Avenue west of Ferguson Avenue, Wellington Street from Charlton Avenue to Stinson Street and on Stinson Street from Wellington Street east to West Avenue. A 42" Ø watermain goes south from the pumping station by tunnel into the escarpment and then via a vertical shaft up to St.Joseph's Drive and then west along St.Joseph's Drive and Markland Street. On the Mountain, the only major trunk watermains are 36" Ø on Fennell Avenue

crossing the entire study area east-west and a 42" Ø watermain on Limeridge Road from Upper Wellington Street to Upper Wentworth Street. Watermains in the Mountain residential areas are usually located under the boulevard with five feet of cover. On major streets and downtown the location varies but five feet of cover is generally maintained.

3.4.3 Gas

There is one 16" Ø high pressure gasmain which crosses the study area via West 5th Street, South Bend Road, Warren Avenue and Mohawk Road. Relocation of this gasmain would be difficult and costly.
The 8" and 10" diameter gasmains which are shown are medium pressure and would be moderately difficult and costly to relocate.
The smaller diameter low pressure mains used for local distribution would be relatively easier to relocate.
Gasmains are generally four to five feet from the property line with three to four feet of cover.

3.4.4 Bell

Bell Canada has two exchanges in the study area. One is downtown on Hunter Street between MacNab Street and James Street, the other is west of Upper Wentworth Street just south of Fennell Avenue.
From the two exchanges, major buried duct runs carry cables intercity (Toll Cables) between exchanges (Trunk) and within the exchange (Exchange). On Upper James Street south of Mohawk Road, Toll and Exchange cables are carried overhead.
The local feeder cables south of Mohawk Road are approximately 60% buried and 40% aerial while those north of Mohawk Road on the Mountain are all aerial. Below the escarpment, the cables are buried on the major streets, while in the backstreets and alleyways the majority of local cable runs are aerial.
Buried Bell Cable is generally under the boulevard with approximately three feet of cover but location and depth of cover may vary.

3.4.5 C.N.CP. Telecommunications

The most important of the C.N.C.P. cable routes in the study area is from

a tower west of Upper Wellington Street just north of McElroy Road, south on Upper Wellington Street, west on Concession Street, through the Sam Lawrence Park, down the escarpment, north on Ferguson Avenue, west along the T.H. & B. Right-of-Way and north again on James Street. Some portions of this route between Concession Street and the T.H. & B. are aerial, all other C.N.C.P. routes are buried.
C.N.C.P. cable is often in the same ducts or in the same general location as buried Bell Cable.

3.4.6 Hydro and Street Lighting

Residential, commercial and industrial electrical supply and street lighting in the City of Hamilton are under the control of Hamilton Hydro. Ontario Hydro has a sub-station and buried high voltage feeder cables on Wilson Street in the north of the study area.
There are four Hamilton Hydro sub-stations in the study area: Wellington Sub-Station on Mohawk Road just east of Upper Wellington Street, Mountain Sub-Station on Upper Wentworth Street south of Queensdale Avenue, Central Sub-Station on John Street south of Augusta Street and the most important - Hughson Sub-Station on Hughson Street at Rebecca Street.
The main feeder cables are 4 KV and 13 KV. All the 13 KV and most of the 4 KV cables north of the escarpment are buried. On the Mountain, most major feeder cables are aerial but some on West 5th Street, Upper James Street, Mohawk Road and Upper Wentworth Street are buried. The local feeder cables south of Mohawk Road are generally buried, while north of Mohawk Road and south of the escarpment they are aerial. North of the escarpment, local feeder cables on some of the major streets are buried but on the local streets, the majority are aerial. Relocation of 4 KV and 13 KV buried and aerial cables may be costly.

3.4.7 Roads

Within the City of Hamilton, all arterial roads are under the jurisdiction of the Regional Municipality of Hamilton-Wentworth. In the study area these are:

- Mohawk Road, Fennell Avenue and Concession Street

- West 5th Street, Upper James Street, Upper Wellington Street and Upper Wentworth Street
- James Mountain Road, the Jolley Cut and the Claremont Hill Mountain Access Road (CHARM)
- Arkledun Avenue, St. Joseph's Drive west of John Street, Herkimer Street and Charlton Avenue
- Main Street, King Street, Wilson Street and Cannon Street
- Bay Street, James Street, John Street, Wellington Street and Victoria Avenue

The remaining streets are under the control of the City of Hamilton. Standard Road construction in the City is a 6" or 8" concrete base with 3" of asphalt.
Widening or partial reconstruction of the Mountain Access Roads (James Mountain Road, Jolley Cut CHARM) could present major problems and high costs.

3.4.8 Hamilton Street Railway

From the service and utility viewpoint, interference with the overhead trolley bus power and feeder cables is the main concern.
The type of guideway proposed for the I.C.T.S. is probably compatible with the suspension of trolley bus power lines either from or below the guideway provided the necessary clearances can be maintained. From this standpoint, no major conflicts are envisaged.
The question of electrical interference between trolley buses and the I.C.T.S. should be the subject of a separate review.

3.4.9 Cable T.V. and Traffic Signal Control Cables

Cable T.V. service in the study area is provided by several separate companies. Cables are buried under boulevards or sidewalks with minimum cover, often jointly with Bell and/or hydro cables. Relocation of these cables is not a major problem.
Each intersection that is controlled by traffic signals has control cables linking the individual signals to the control panel. On the major downtown streets, sets of lights are linked by buried cables to provide co-ordinated operation. Relocation of these cables is not a

major problem.

3.4.10 Railways

Two companies have railway tracks within the study area. The Toronto, Hamilton & Buffalo Railway, now owned by Canadian Pacific, has its main tracks running east-west across the study area from a tunnel below Hunter Street behind City Hall, through the station at Hunter Street and Hughson Street to the east limit of the study area just north of the escarpment face.

There is a single line Canadian National Railways track which runs from the limit of the study area south on Ferguson Avenue to join the T.H.& B. tracks running easterly.

Associated with the railways and within their right-of-way are signalling and other communication cables and storm drainage systems.

3.5 MAJOR UTILITY AND MUNICIPAL SERVICE FACILITIES

Drawing No. X-80629-G10 is a composite plan showing the major utility and service routes and facilities which represent significant potential conflicts to the transit facility. These are:

Sewers	- 3' x 4' box sewers and larger
Water	- Major Pumping Stations and watermains of 30" and over
Gas	- Intermediate and high pressure gas mains
Hydro	- Major Sub-Stations and Ontario Hydro High Voltage buried cable
Bell	- Exchanges and Toll Cable Routes
C.N.C.P.	- Major telecommunication cable route
Jackson Square	- Truck Tunnel and Central Utilities Plant

Relocation either permanently or temporarily of these major utility and municipal service facilities would involve a high degree of difficulty and cost. It can be seen however, that few major roads in the study area are free of at least one such major facility.

3.5.1 Upper Zone

The east-west arterial roads in this zone are Mohawk Road, Fennell Avenue

and Concession Street, and north-south are West 5th Street, Upper James Street, Upper Wellington Street and Upper Wentworth Street. These roads vary in width and standard of construction but reconstruction or widening of any will be costly and may involve acquisition of property. Many of the major utility and municipal service routes follow these arterial roads:

Mohawk Road	- High pressure gasmain, major Bell ducts, large box combined sewer from Upper James Street to Hayden Street
Fennell Avenue	- Trunk watermain, trunk sewer, major Bell duct
West 5th Street	- High pressure gasmain from South Bend Road to Fennell Avenue
Upper James Street	- Intermediate pressure gasmain, major Bell duct (overhead south of Mohawk Road)
Upper Wellington St.	- Large box sewer from Fennell Avenue to Inverness Avenue, major C.N.C.P. telecommunication cable duct north of McElroy Road
Upper Wentworth St.	- Large box sewer and major Bell ducts north of Fennell Avenue

Other major utility and municipal service routes are located on collector streets such as:

Limeridge Road	- 42" Ø watermain between Upper Wellington Street and Upper Wentworth Street and Bell ducts
South Bend Road	- High pressure gasmain
Inverness Avenue	- Large box sewer, Bell ducts

Major roads that are notable for their lack of major utilities and services are: Concession Street, Queensdale Avenue, Brucedale Avenue, Limeridge Road and West 5th Street, Upper Wellington Street and Upper Wentworth Street south of South Bend Road.

3.5.2 Escarpment Zone

There are three access roads up the escarpment in the study area: James Mountain Road, Claremont Hill Mountain Access Road (CHARM) and

the Jolley Cut. Widening or partial reconstruction of these roads due to the construction of transit guideways above or adjacent to them would be very costly.

Major utility and municipal service routes in the escarpment zone include:

- A combined sewer from Upper James Street to James Street North
- An intermediate pressure gasmain and major Bell duct from Upper James Street to John Street
- Partly aerial and partly buried major C.N.C.P. Telecommunications cable from Concession Street to Ferguson Avenue

Relocation of utilities and municipal services in the escarpment zone is likely to be costly.

3.5.3 Lower Zone

The arterial roads in the study area downtown zone are Main Street, King Street, Wilson Street and Cannon Street running east-west and Bay Street, James Street, John Street, Wellington Street and Victoria Avenue running north-south.

Many of these streets and other downtown streets have buildings on both sides with no setbacks. Widening of these streets would, therefore, involve costly property acquisition. On some of the narrower streets it may not be possible to construct a double guideway with adequate clearance from the buildings.

There are several major utility and municipal service facilities in the Downtown Zone. These include:

- The Central Utilities Plant which extends under King Street
- Truck tunnels for the Jackson Square Redevelopment Area
- Bell exchange on Hunter Street
- Hamilton Hydro main sub-station on Hughson Street
- Ontario Hydro sub-station on Wilson Street
- Water pumping station on Ferguson Avenue
- St. Joseph's Hospital Aerial Walkway across St. Joseph's Drive

Conflicts with these facilities would be extremely costly.

Most of the major utility and municipal service routes are located on the arterial roads:

Main Street - Bell ducts, intermediate pressure gasmain east of Walnut Street

King Street	- C.N.C.P. Telecommunications cable west of James Street
Wilson Street	- Two high voltage Hydro ducts east of Elgin Street
Cannon Street	- Intermediate pressure gasmain, large box storm sewer between John Street and MacNab Street
James Street	- Large box combined sewer, major C.N.C.P. Telecommunications cable
John Street	- Intermediate pressure gasmain, large box sewer, major Bell ducts south of Hunter Street
Wellington Street	- 30" Ø watermain south of Stinson Street
Victoria Avenue	- 66" Ø storm sewer from Wilson Street to the T.H. & B. Railway

Other downtown streets north of the T.H. & B. Railway that have major utilities and municipal services include: MacNab Street, Hughson Street, Catharine Street, West Avenue, Jackson Street and Hunter Street.

Non-arterial streets south of the T.H. & B. Railway with major utility and municipal services include: Robinson Street, Charlton Avenue, Markland Avenue, St. Joseph's Drive, Catharine Street, Ferguson Avenue and West Avenue.

The two railway lines (T.H. & B. and C.N.) represent major potential conflicts. The T.H. & B. must be crossed at some point and the C.N. tracks run down Ferguson Avenue from the T.H. & B. to the north limit of the study area.

Of the arterial roads, Bay Street is free of major utilities and municipal services and King Street and Wilson Street and Wellington Street have few of these facilities.

Other downtown streets of reasonable width with few, if any, major utilities or municipal services are Rebecca Street and King William Street.

4.0 STRUCTURAL

4.1 GENERAL

The ICTS will be supported for most of its length on an elevated guideway, with tunnel sections being considered on some of the alternate routes in the escarpment area. The structural components of the elevated portion of the guideway system, as developed by UTDC, are two parallel continuous cast in place pre-stressed box girder beams each carrying one track. The girders are supported by single column piers with capping beams built flush with the soffit of the guideway girders. This system, modified for pre-cast construction, was applied to the proposed alternative routes and reviewed with the planning team for feasibility, cost, special construction requirements and disruption to existing services. Various alignments were eliminated that were not structurally practical or feasible.

4.2 ALTERNATIVE ALIGNMENTS

For discussion purposes the corridor is divided into three zones: The Upper Zone, The Escarpment Zone and The Lower Zone.

4.2.1 Upper Zone

Structurally, there is little to differentiate between the various routes in the Upper Zone. The most significant problem will be the location and construction of the portals of the various tunnel routes as the guideway emerges from the ground. From the point that the portal starts until the guideway has reached sufficient elevation to clear vehicular traffic, there will be a physical barrier of approximately 500 ft. cutting off the access to private and public facilities.

4.2.2 Escarpment Routes

The structural costs and construction problems that will be encountered in building the guideway on the escarpment is directly related to the soil conditions and escarpment profile. The differential movement that the

guideway can tolerate is limited, and any route that transverses the talus will be more expensive due to the cost of either stabilizing the talus to prevent further long term movements or designing the caissons to resist the loads due to the movements. For a more detailed description of the soil conditions see Section 2.

The escarpment routes have been reviewed in general terms to highlight major concerns or potential problems in addition to the soil conditions. On Route E1, the James Mountain Road, it would be very difficult to construct the guideway past the West 5th bridge, because of the steepness of the rock face to the North, extensive rock cuts and property acquisition required to the South, and insufficient clearance under the West 5th bridge.

On Route E3, the Claremont Hill Drive, the centre median will need to be widened for the guideway columns thus widening the bridge on the Claremont Drive. The apartment building on the South side of Arkledun will interfere with the routes E3, E4 and E8 if they are located on the North side of the road. Route E5 appears to conflict with the rail siding south of the T.H. & B. Railroad. Route E9 conflicts with the piers of the Arkledun Bridge over the Claremont Hill Drive.

The engineering modifications required to overcome these conflicts will increase the cost of the guideways in these areas.

4.2.3 Lower Zone

The 90^{o} curve at street intersections in the downtown area presents a restrictive condition. Except for the inside to inside curve which requires additional property, all other configurations will require a support column in the median of the road.

The alignments that go over Jackson Square create severe difficulties for the constructor. It would be unlikely that any heavy equipment or large capacity cranes could be utilized in this area. Construction of Piers and Foundations must be carried through several levels of existing floors. Since precast segments could not be lifted into place, the guideway would be cast in place, with form work shored through two levels of the Plaza, causing disruption to existing facilities in the Plaza.

Preliminary soils information indicate that bearing piles or caissons would be required in this area to limit the deflections of the high free-standing columns. Driving piles would be out of the question considering the limited clear height to the 1st level of the existing structure. Therefore, it would be necessary to dig caissons by hand, a very time consuming and expensive procedure.

The guideway structure should be kept a completely separate structure from the existing building to avoid any transfer of vibrations from the guideway to the building. Sealing this gap for weather is a potential maintenance problem.

Since the construction of a station over Jackson Square is not contemplated at this time, a peripheral route within the street allowance would achieve similar effects as a route over Jackson Square but without encountering the special construction problems.

4.2.4 Railways

There are special considerations for those routes that go over or along the Railway R.O.W. For example, clearance requirements are greater for the railway than for vehicular traffic, effecting an increase in the height of columns.

The route along Ferguson Avenue has a number of unique problems. The typical pier could not be used and, therefore, a special two column bent would be required to support the guideway. This would also eliminate future sidings to potential users.

Any disruption or temporary blockage to rail traffic due to construction, or maintenance during operations, would incur a severe cost penalty to the railways,as detouring rail traffic in this area is very difficult.

Access for maintenance and inspection vehicles must be provided in the final guideway-railway configuration as well as in the agreements signed with the railways.

Any possibility of planned grade separations between railways and main roads must be identified at this time. It would be extremely disruptive and costly to reconstruct the guideway at some future time to accomodate a grade separation.

4.3 RELATIVE COSTS

In order to facilitate the comparison of the alternate routes, the relative costs of each type of construction that could occur on the various routes is presented. These figures are approximate only, based on the preliminary level of design and data available at this time. As a base, a cost factor of 1.0 has been assigned to a standard precast, pre-stressed, elevated double track guideway supported on shallow spread foundations on straight alignment with uniform spans of 80' to 100'. This figure includes the cost of the foundations, columns, guideway structure, track and track hardware but does not include the cost of relocating utilities or acquisition of property. Other types of construction are compared to this base number. The relative cost factor numbers for other types of construction are as follows:-

Double Track Guideway (straight)	1.0
Single Track Guideway (straight)	.6
Double Track Guideway on Caissons in talus	1.2
Double Track Guideway - Tunnelled in rock	4.6
Double Track Guideway - Tunnelled in talus	5.2
Double Track Guideway - at grade	.3
Double Track Guideway - Cut and Cover (24' Deep)	3.2
Double Track Guideway - Over existing facilities (Jackson Square)	3.0

Other factors that will affect the construction costs of the guideways are:

Restricted Working Areas:

Construction in the downtown area will be more expensive due to the constructed working area, the necessity to provide vehicle and pedestrian access to commercial and public facilities, restricted working hours, maintenance of traffic and public transportation. These restrictions could increase the Cost Factor 20% to 30%.

Accessability to the Construction Site:

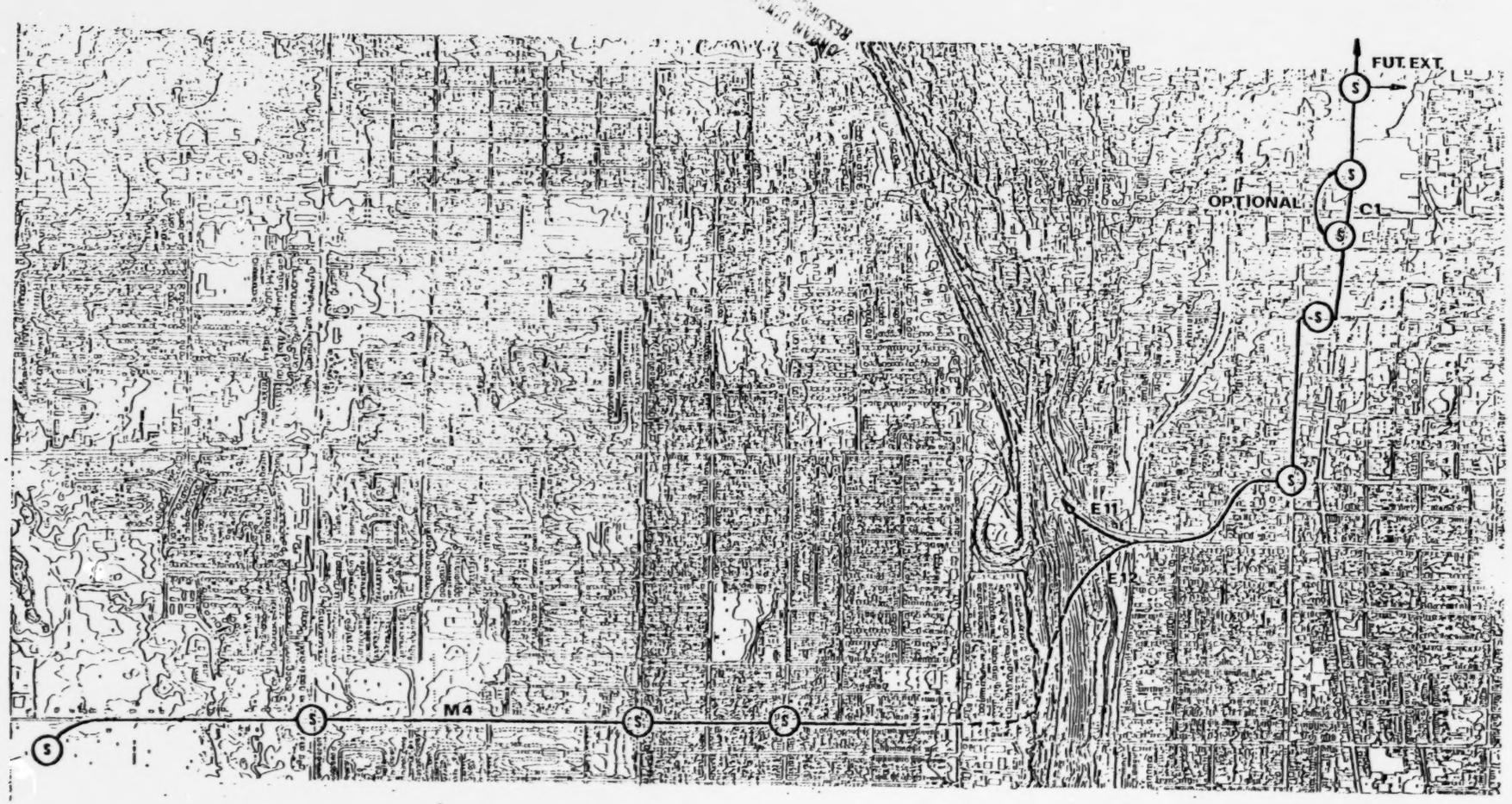
Access roads would be required on some of the escarpment routes, notably E5, E9 and E12. This would increase the cost of those portions of the route by 30%.

Variations in Guideway Alignment:

The cost of the guideway would increase from 10% to 20% if the vertical or horizontal alignment deviate from the typical straight or large radius curve. Small radius curves complicate the manufacture and shipping of the precast units. A greater number of columns and foundations would also be required as curves reduce the capacity of the beams to support large spans. Also, any increase in column lengths or span lengths will increase the structural cost.

4.4 REVIEW OF DESIGN CRITERIA

Although the data received on Design Criteria was not as extensive as required to conduct a complete review, the effect on Task B1, the generation of alternate alignments was minimal. This review must now be done as part of Task B2, as the development of Design Criteria will play an increasingly important role in the analysis of the alternate alignments. In preparation for this task a list of Source of Design Criteria was submitted to U.T.D.C.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E12
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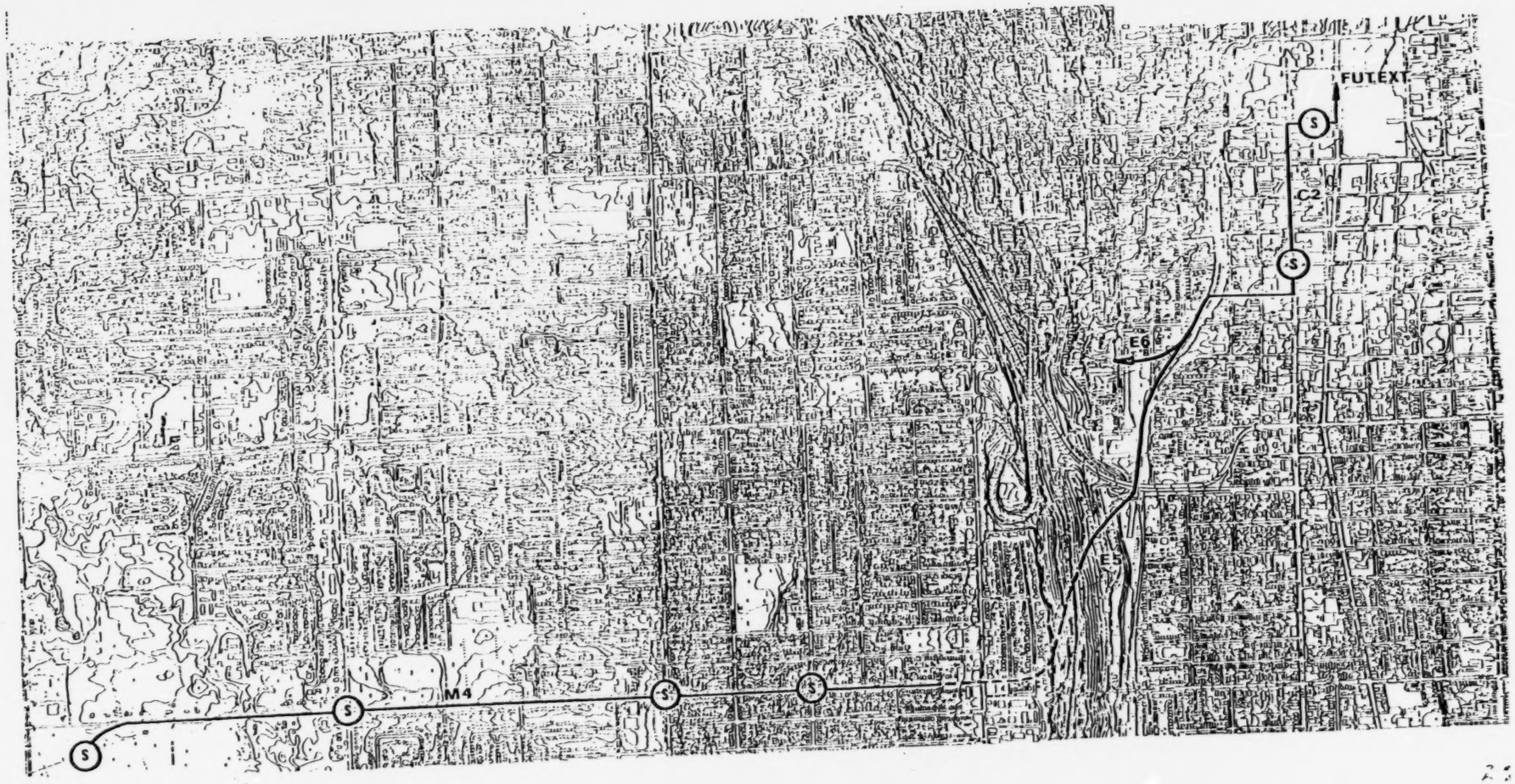
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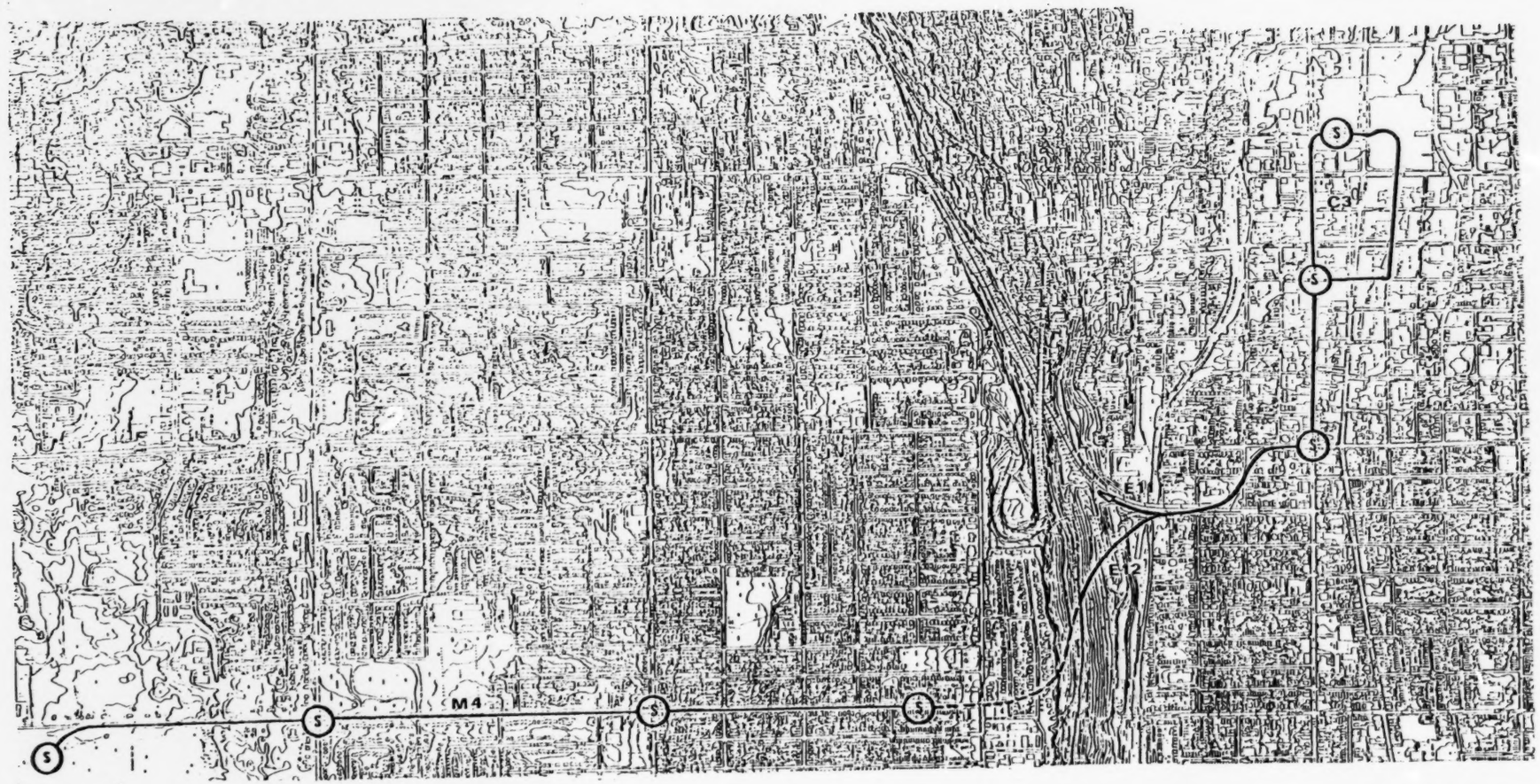
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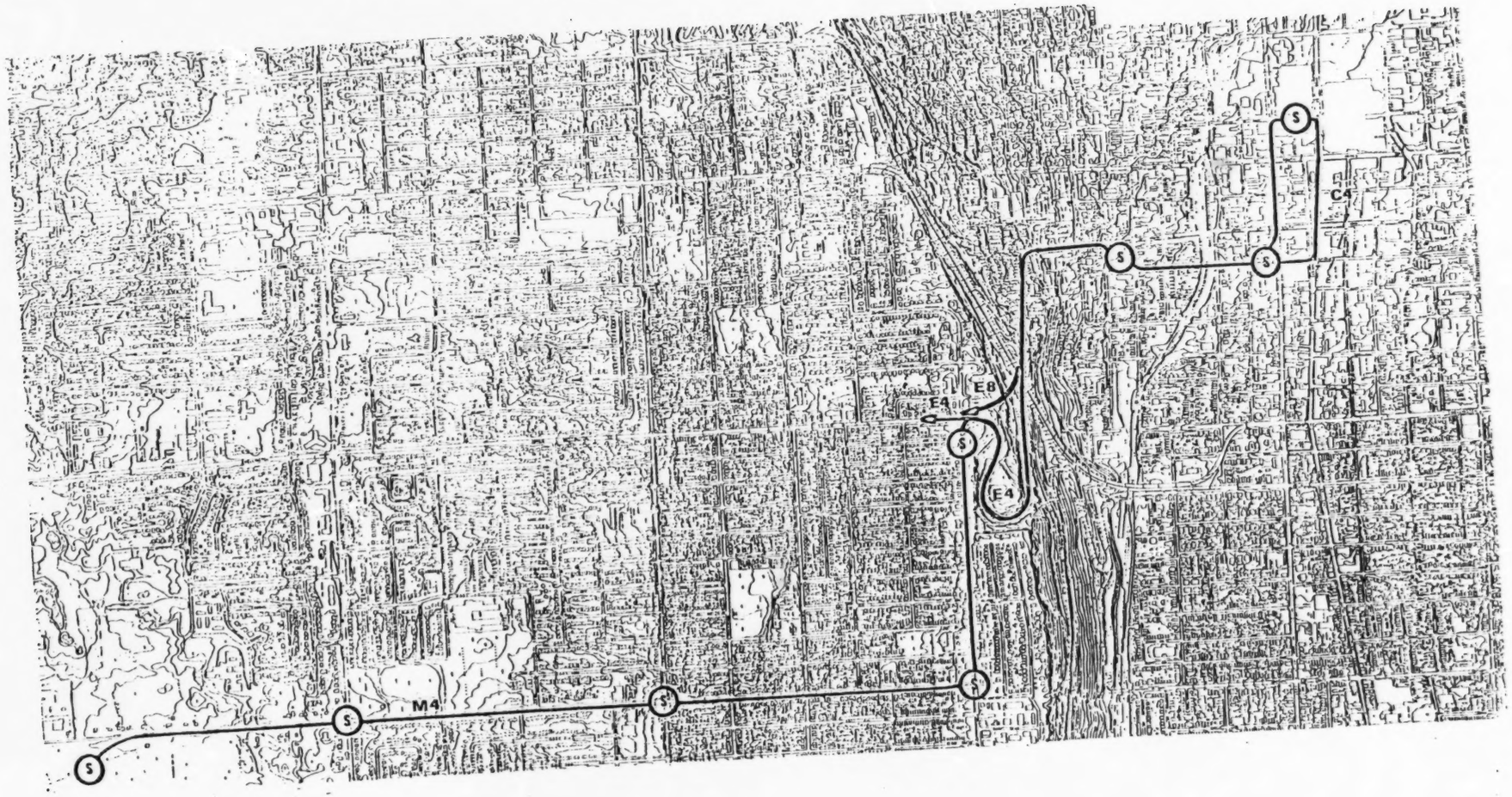
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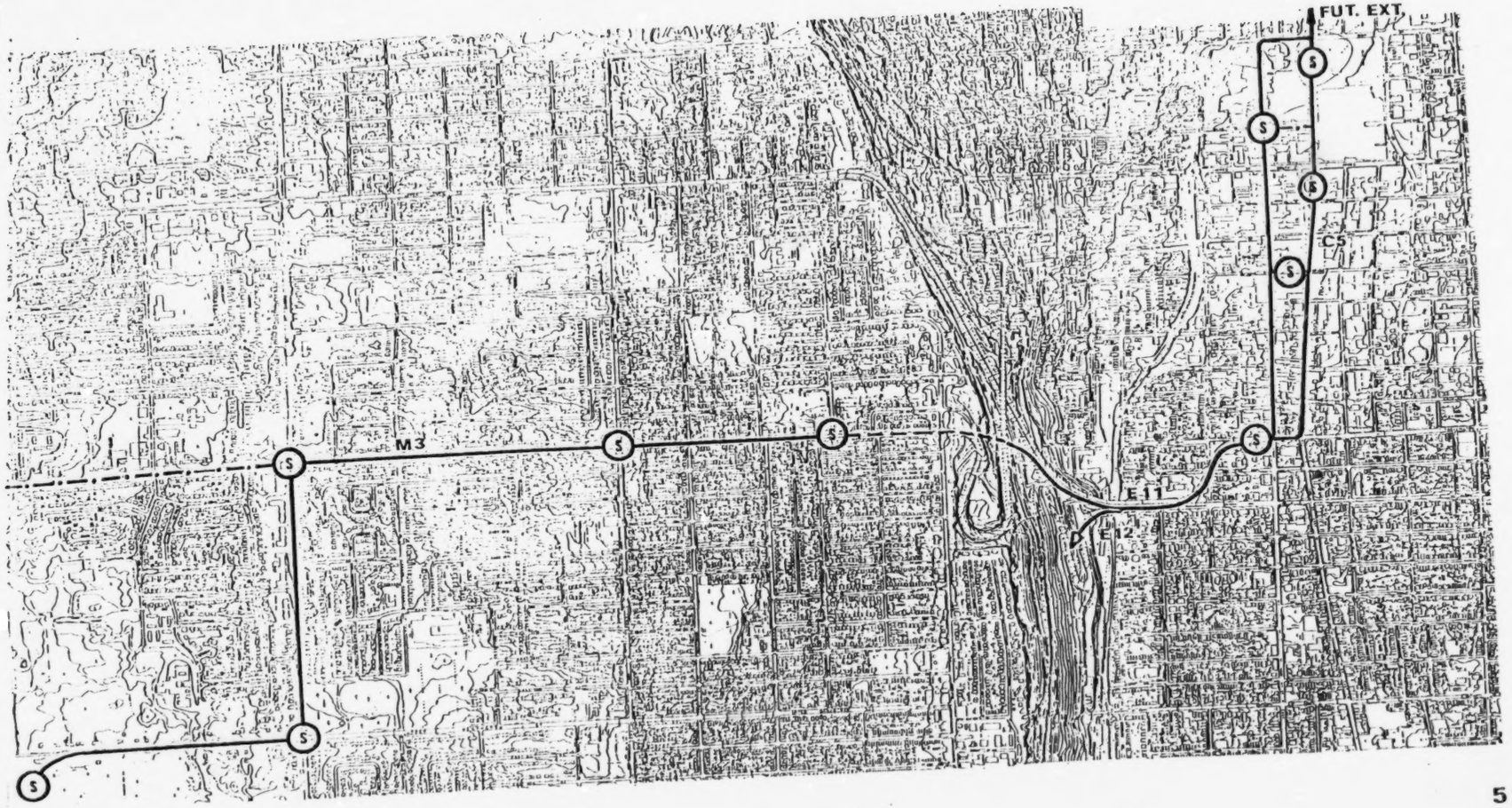
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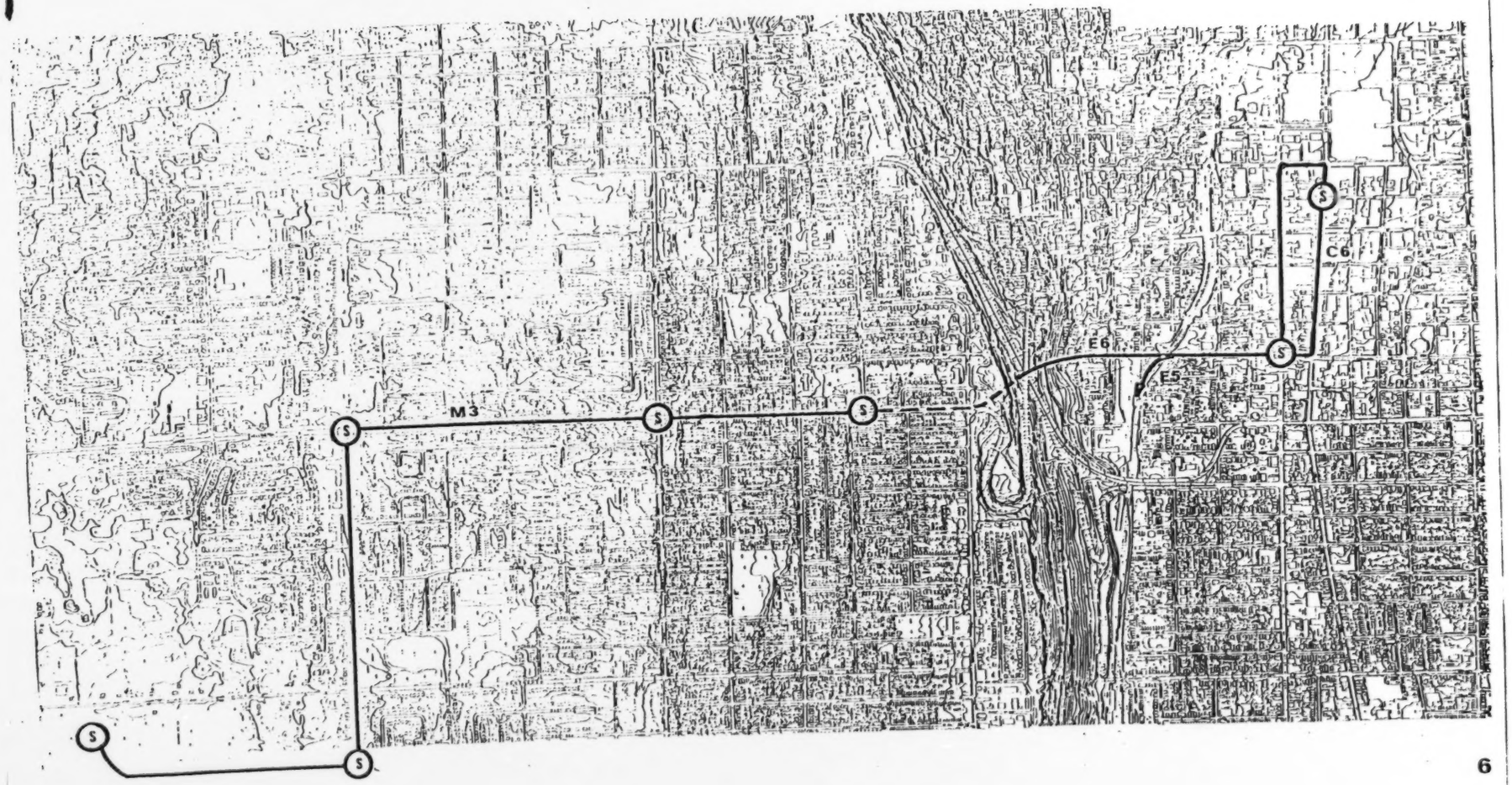
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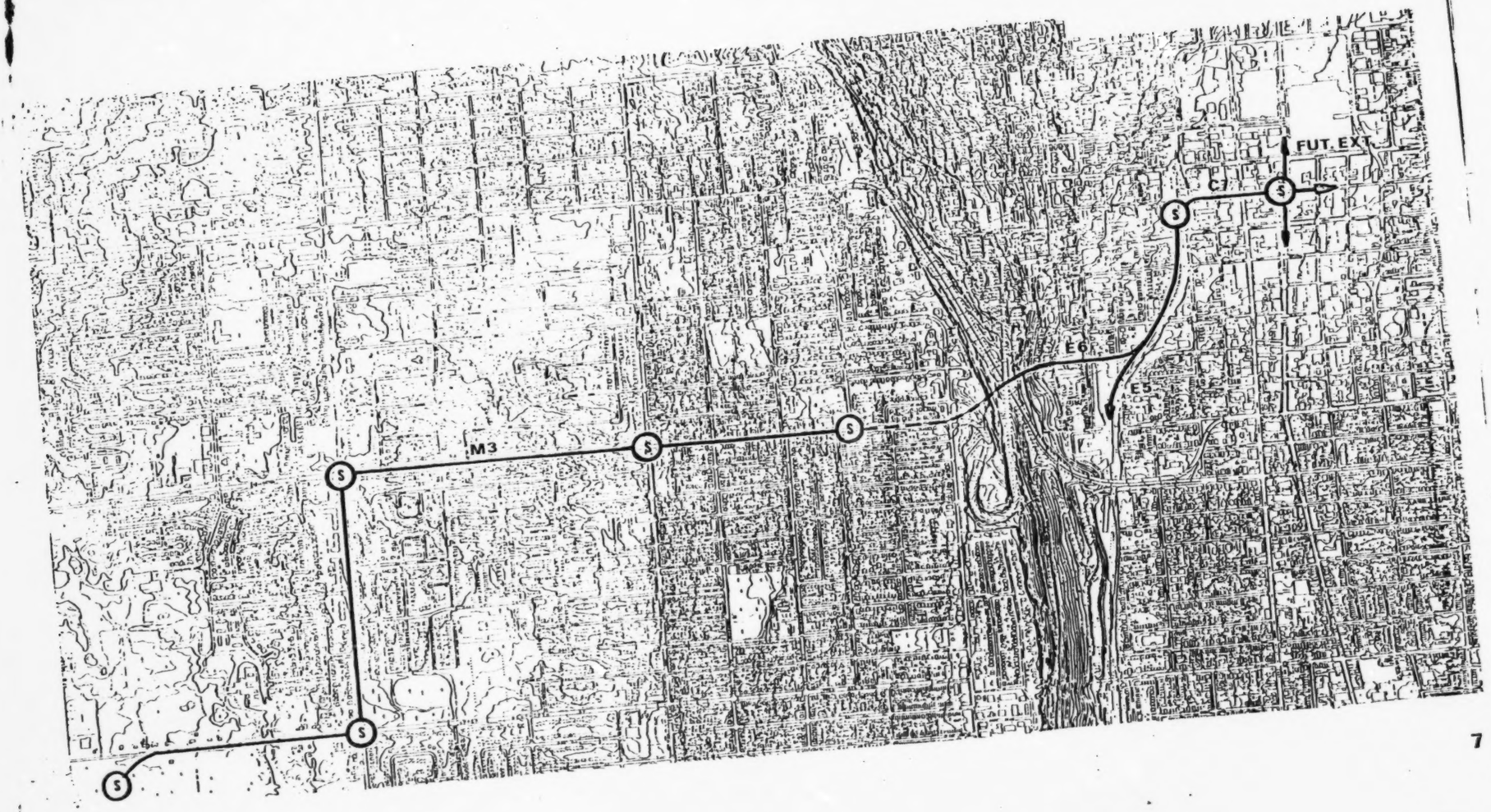
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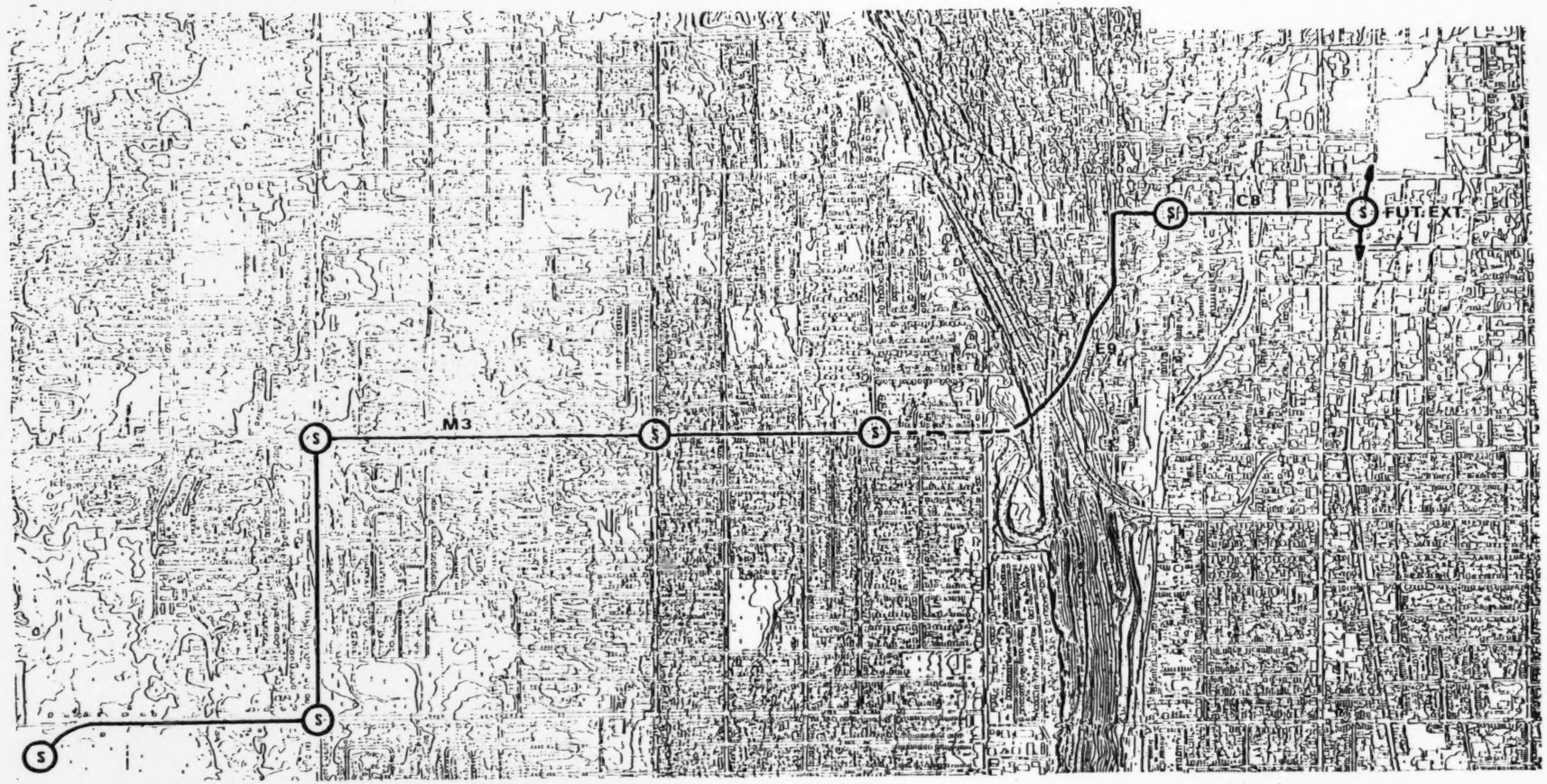
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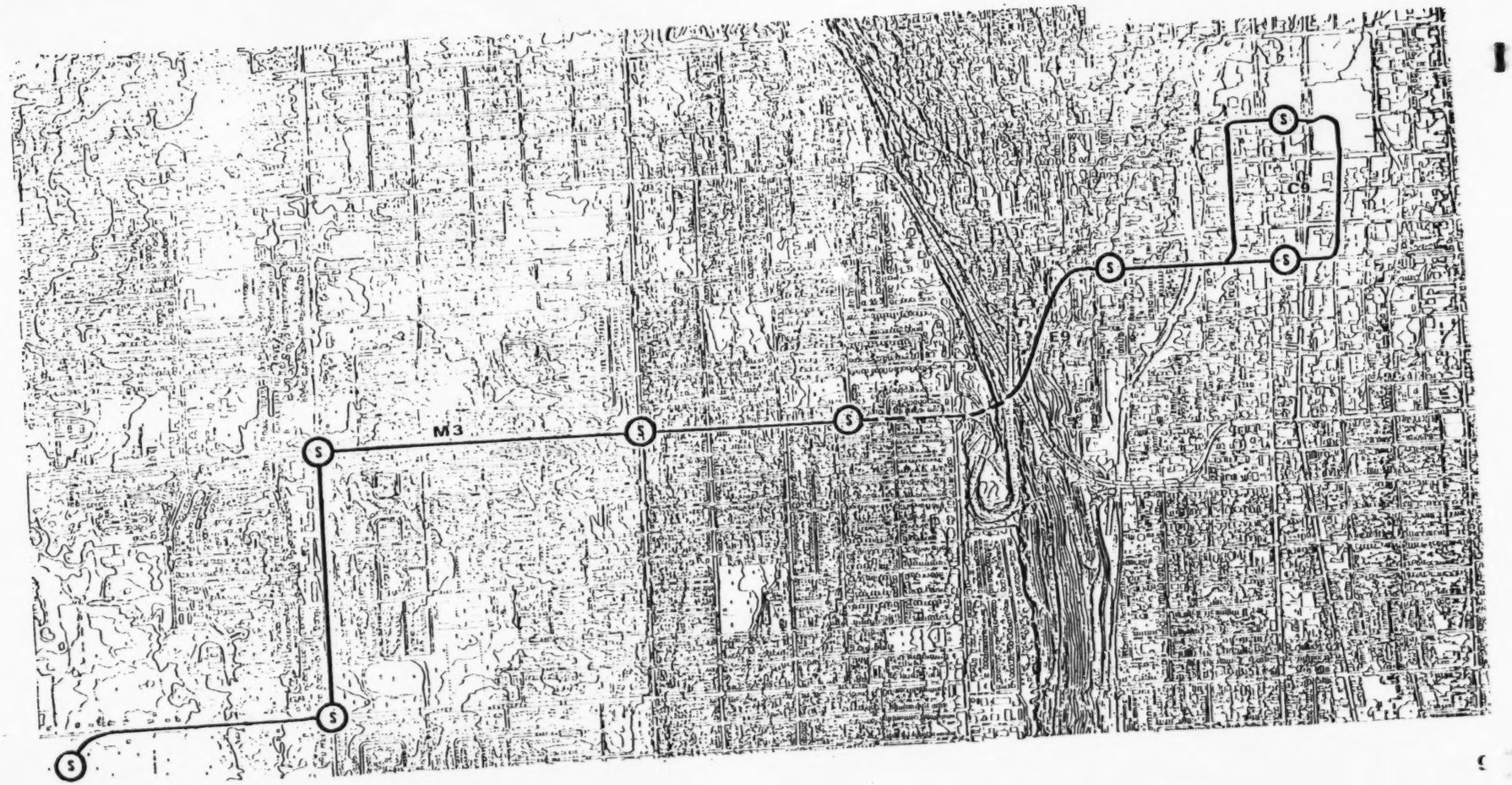
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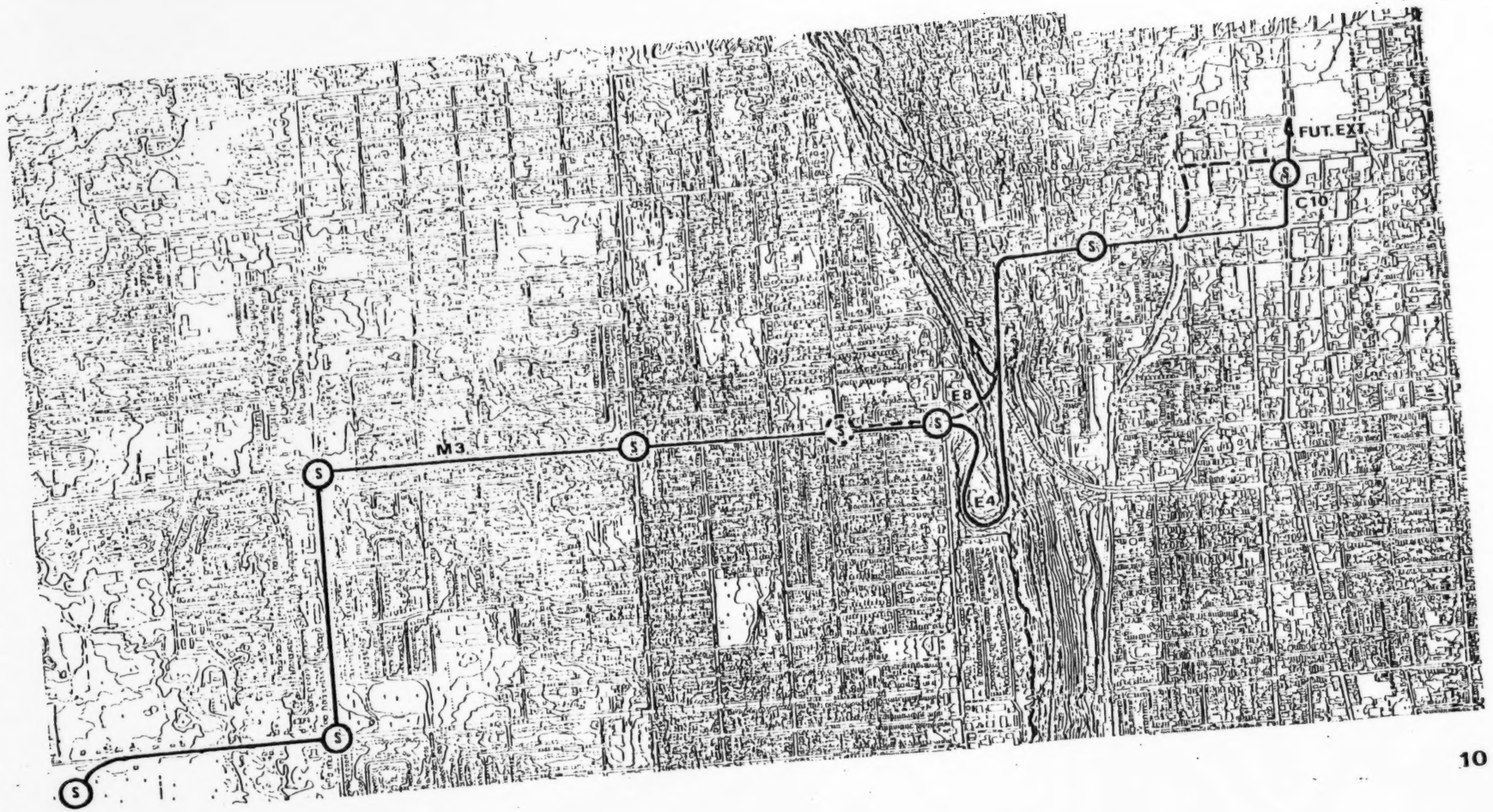
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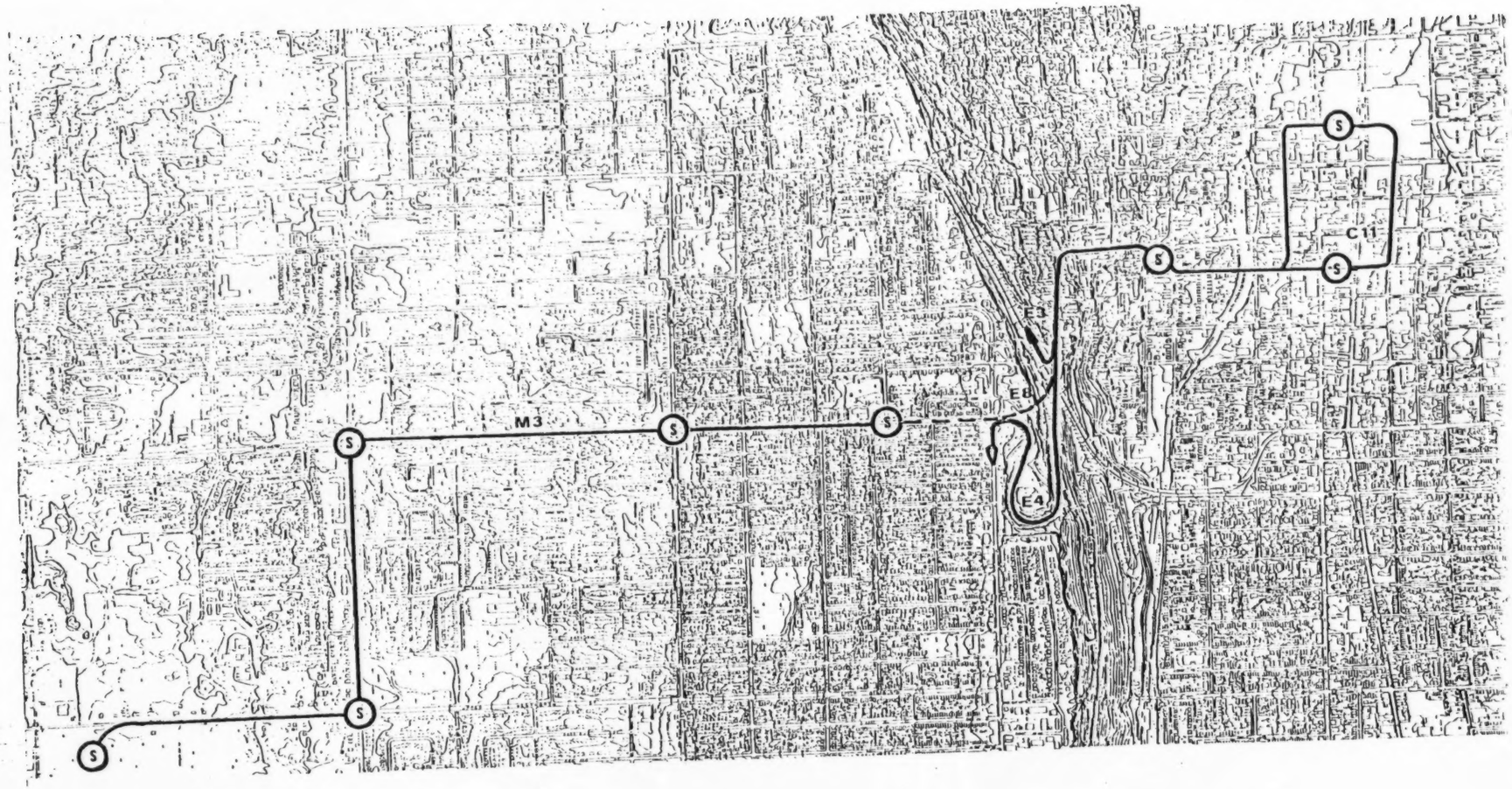
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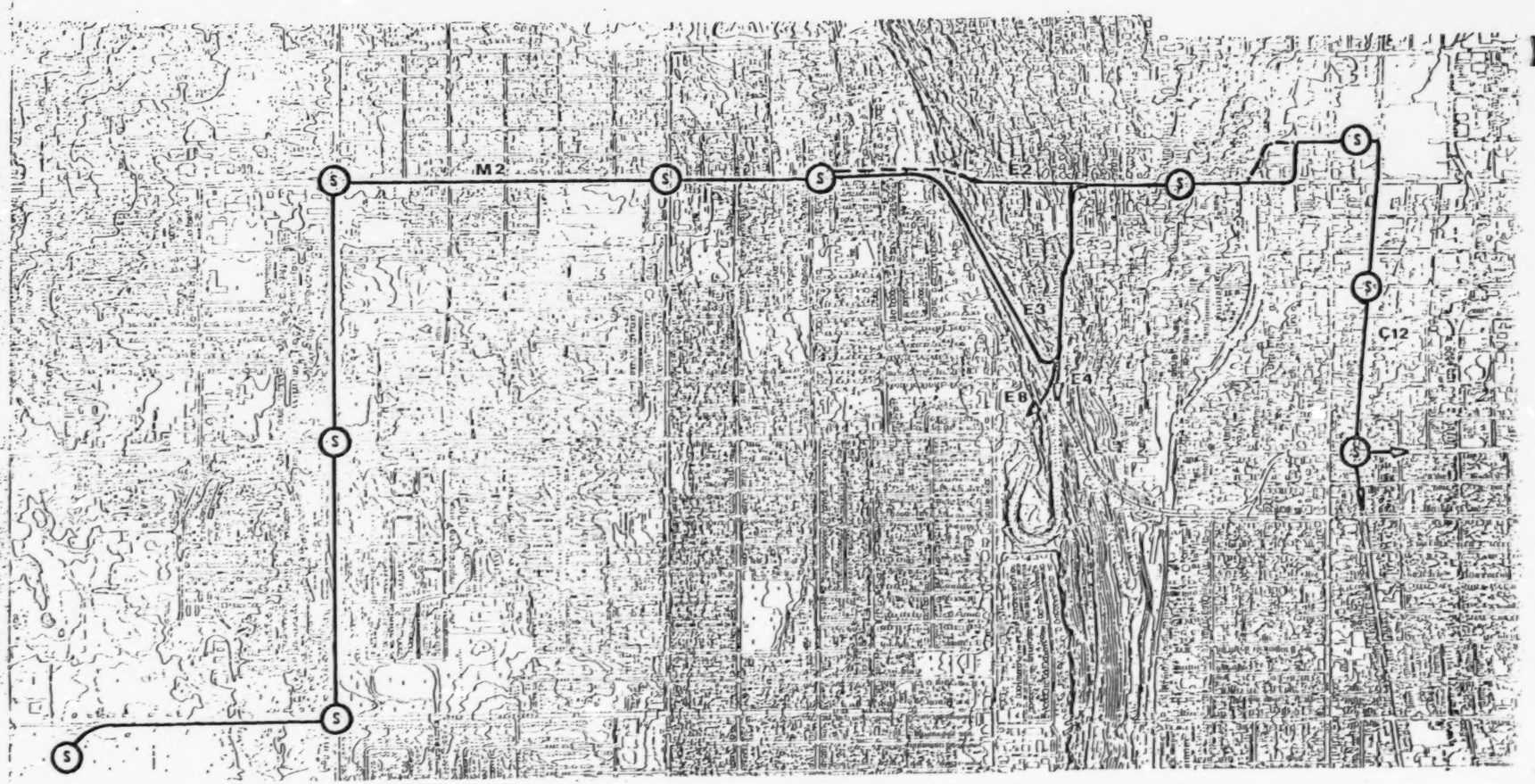
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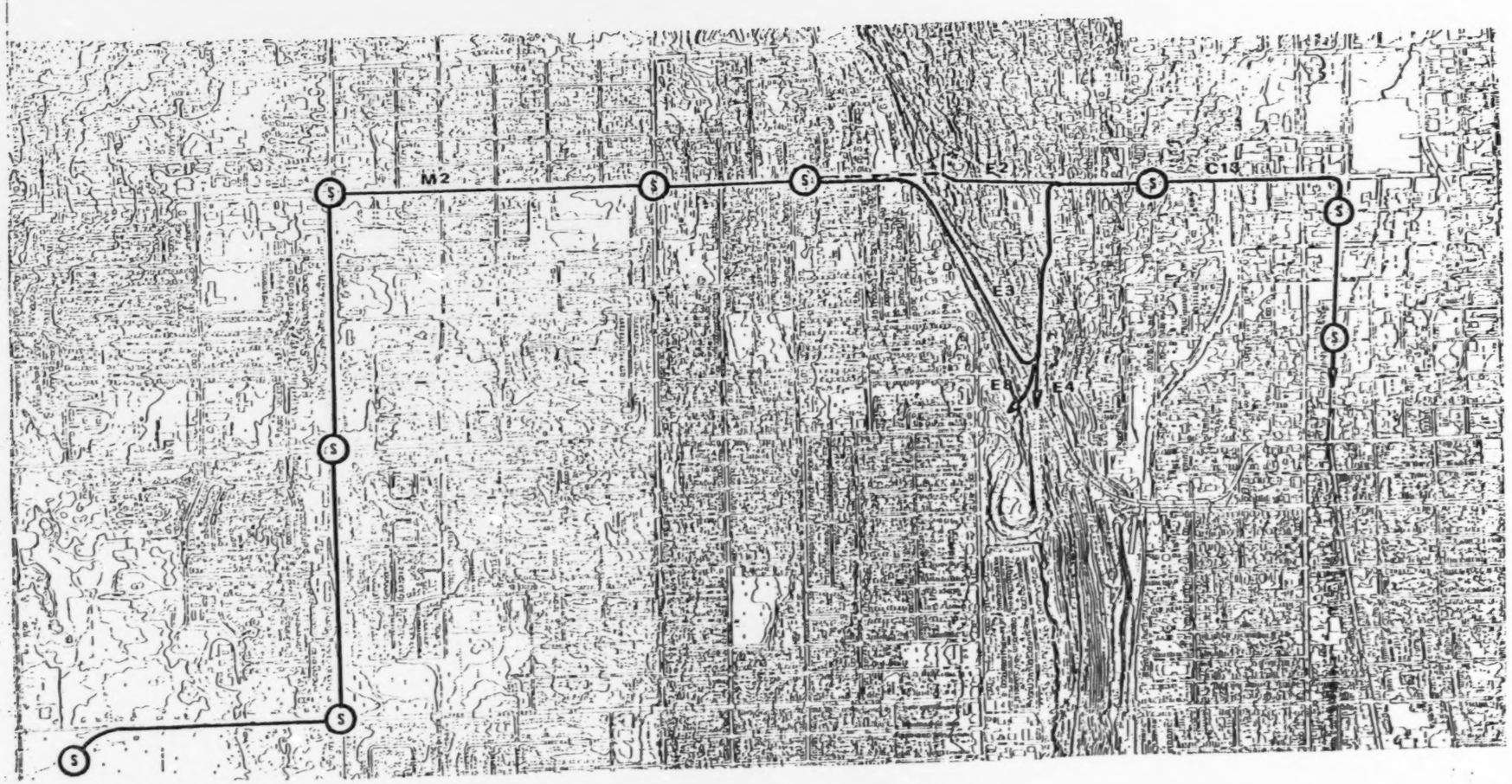
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